SEED COLOR AVOIDANCE BY CAPTIVE RED-WINGED BLACKBIRDS AND BOAT-TAILED GRACKLES

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Abstract: Offensive visual stimuli represent a potentially important component of avian crop damage reduction strategies. Color perception by diurnal birds is highly developed, but the responses of the red-winged blackbird (*Agelaius phoeniceus*) to different-colored food have never been investigated. Red-winged blackbirds and boat-tailed grackles (*Quiscalus major*) cause substantial damage to newly seeded rice in the southern United States, and the examination of color avoidance by these species should contribute to the development of nonlethal methods to reduce depredations. We used rice seed of various colors to conduct a series of feeding trials with captive blackbirds and grackles. Despite variation among individuals and groups of test birds, blue was the least preferred color overall. Differences among species and among background color might affect responses of birds to a given seed color, but, in general, we suggest that blue should be incorporated into strategies for discouraging unwanted feeding by granivorous birds. In particular, further development of visual deterrents should exploit the ability of blackbirds and other species to detect wavelengths in the near ultraviolet.

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For diurnal passerine birds, vision is the principal sense for detecting and selecting food. A particularly important aspect of the visual world of birds is their sense of color. Color vision in birds plays a key role in community ecology and species interactions (Brower et al. 1967), plant pollination (Stiles 1976), and seed dispersal (Willson and Melampy 1983).

Remarkably, the color preferences of perhaps the most widely studied passerine species in North America, the red-winged blackbird, have not been critically examined. Although color has been incorporated into various types of feeding studies, usually as a cue or conditioned stimulus for food-avoidance learning (Mason and Reidinger 1983, Avery and Mason 1997), quantification of the feeding responses of this species to a range of colors is lacking. In a limited evaluation, individual red-winged blackbirds initially preferred natural rice to rice colored with red,

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green, yellow, or blue food coloring (E. Schafer. 1968. The effect of color on food preference in red-winged blackbirds, unpublished report. Denver Wildlife Research Center, Denver, Colorado, USA). After 4 days, however, only the preference for natural over green persisted.

In wildlife management, knowledge of bird responses to color has potential application in the areas of crop protection (Greig-Smith and Rowney 1987, Rodriguez et al. 1997) and chemical hazard avoidance (Kalmbach and Welch 1946, Brunner and Coman 1983, Gionfriddo and Best 1996).

Red-winged blackbirds, boat-tailed grackles, and other species regularly cause substantial economic loss to newly seeded rice in the southern United States (Wilson et al. 1989, Decker et al. 1990), and bird-deterrent seed treatments are potentially useful in reducing damage (Avery et al. 1998). Regulations in the United States require that repellents and pesticidal seed treatments include a color. Thus, it seems desirable to use a color that will reduce the chance of unwanted ingestion by birds. In this study, our objective was to determine the colors least attractive to rice-eating birds so that this information can be incorporated into strategies to reduce crop depredations. Potentially, such information will also be applicable to the development of methods to reduce accidental ingestion of pesticides by birds.

METHODS

General

The study was conducted at the Florida Field Station of the U.S. Department of Agriculture's National Wildlife Research Center in Gainesville, Florida. Red-winged blackbirds and boat-tailed grackles were trapped near Gainesville and maintained in captivity up to 4 months before testing. Birds were housed by species in 1.3- × 1.3- × 1.7-m cages in a roofed outdoor aviary with ad libitum access to quail starter feed (Hillandale Farms, Lake Butler, Florida, USA) and water. After testing, each bird was banded and released. Rice seed was prepared by mixing either 2 mL or 4 mL of acrylic latex paint with rice in 1-kg batches to create visually distinct hues that coated the seeds evenly. Water-soluble food colorings were not satisfactory, because they would not evenly color the rice seed hull.

Test 1. Individual Red-Winged Blackbirds 30-Min and 3-Hr Pairwise Color Preference

The objective of this test was to document individual blackbird responses to paired presentations of different colored rice seed. We evaluated preferences in 30-min and 3-hr tests. We used 12 adult male blackbirds in each test. Four days before the start of the test, we removed blackbirds from their holding cages and assigned them to visually isolated individual test cages (45 × 45 × 45 cm) equipped with automatic waterers in a roofed outdoor aviary. Red-winged blackbirds were acclimated 4 days to feeding on untreated rice seed from gray ("light neutral gray"; Smithe 1975) plastic food cups.

Five colors of seed were tested: red ("geranium"), white, blue ("cerulean blue"), yellow ("straw yellow"), and green ("peacock green"). The 5 colors produced 10 color pairs, each of which was presented to each bird in a randomly determined sequence over a 10-day test period. On each test day, maintenance food was removed at 0700, and 1 gray test cup containing that day's color pairing (5 g of each color treatment) was presented to each bird at 0800. Aluminum pans beneath each cage caught spillage. After the daily trial, cups and pans were removed and maintenance food returned. We reweighed intact seeds separated by color from each cup and pan to determine consumption.

We used analysis of variance (ANOVA) to analyze the 30-min and 3-hr trials as balanced incomplete block designs (PROC GLM; SAS Institute 1988). Bird, color, and their interaction were the main effects. We examined differences in rice consumption between pairs of colors via least-square means in post hoc comparisons.

Test 2. Individual Red-Winged Blackbird 5-Min Color Preference Trial

The objective of this test was to document the immediate responses of individual blackbirds to rice seeds of different colors, given simultaneous and equal access to all choices. Each of 12 blackbirds received 1 gray food cup. The cups held 30 seeds of each of 7 color treatments, for a total of 210 seeds. The seeds were mixed and loosely distributed so that each color was equally accessible. In addition to the 5 colors used in Test 1, we added black ("blackish natural gray") and tan ("pale horn color"), the latter to mimic the color of a natural rice seed

coat. We anticipated that a hungry blackbird would eat approximately 30 seeds in 5 min. We wanted a bird to be able to fill-up on its favorite color without being forced to eat an unfavored alternate. Maintenance food was removed at 0730, and test cups were presented at 0930 for 5 min. Aluminum pans below the cups caught spillage. A second 5-min trial was conducted at 1000, and the blackbirds were then given maintenance food. We repeated the procedure on day 2 with the same birds.

After each trial, whole intact seeds remaining in cups and spill pans were sorted by color and counted. These data were then subjected to repeated-measures ANOVA to test the hypothesis of no color preference. Tukey's HSD test was applied to separate means a posteriori (Steel and Torrie 1980).

Test 3. Group Red-Winged Blackbird Multicolor Pen Test

This test was designed to determine color preference or avoidance by groups of blackbirds exposed to rice seed of various colors. Blackbirds were taken in groups of 3 from holding cages and randomly assigned to individual outdoor test pens (3.1 × 9.1 × 1.8 m) equipped with shaded perches, a waterer, and a feeding station. When feeding, test birds were visually isolated from birds in other pens. The seed was presented by placing 10 g of a single color in a small terra cotta ("cinnamon"; Smithe 1975) pottery dish or a gray plastic cup. Each dish or cup was then placed inside a larger plastic spillage pan. Seven such feeding stations, 1 for each seed color (the same as used in Test 2), were set in a circular array with partitions (30 × 40 cm) separating the stations. Locations of colors within the array were randomly determined each day for each pen.

On day 1, all 7 colors were presented to each set of 3 birds. We then reduced the number of colors by 1 each day for each test group by eliminating from further testing the color that was consumed the most during that day's trial. We reasoned that birds would preferentially consume seeds with the least offensive colors. Thus, after 4 days' of testing, each group's 3 least preferred colors remained.

For each color of seed cup, terra cotta and gray, we tested 8 groups of 3 birds each. When not being tested, birds received quail starter as maintenance food. On test days, maintenance food was removed at 0700, and the test seed presented at 0800. After 3 hr, we removed the test cups and spill pans and replaced the maintenance food. We reweighed intact seeds to determine consumption. A chi-square test statistic was generated for each cup color by comparing the observed number of times a color remained at the end of the experiment to the expected number (3/7 × 8) under the null hypothesis of no preference. We then repeated the analysis with results from all 16 sets of birds to test the null hypothesis that all 7 colors were selected equally. We then examined the individual contribution of each color to the overall chi-square to determine which colors deviated most from expected.

Test 4. Individual Boat-Tailed Grackle Multicolor Pen Test

This test was conducted to obtain comparative data on another species of rice-depredating bird, the boat-tailed grackle. Male grackles were removed from holding cages and placed individually in outdoor pens (3.1 × 9.4 × 1.8 m) with shaded perches, waterer, and maintenance food (rice plus quail starter). Two groups of 8 male grackles were tested in successive trials following the same procedures as for blackbirds in Test 3. As with the blackbirds, after day 4, the 3 least preferred colors remained for each grackle. Results were evaluated in chi-square tests to determine if colors were avoided with equal probability.

Test 5. Red-Winged Blackbird Groups in Flight Pen

Within a 0.2-ha flight pen at the Florida Field Station, we plowed, smoothed, and seeded a 12- × 12-m plot with 1 kg of rice seed. The enclosure results (Test 3) showed that blue, white, and green were the least favored colors of blackbirds, so we used equal parts of those 3 colors plus tan seeds for comparative purposes. We marked out 20 sampling quadrats (0.19 m^2) and, after seeding, set them so that each held 12 seeds of each of the 4 colors. Ten male blackbirds were allowed access to the test plot from 1000 Monday until 1000 Friday. Counts of seeds remaining on the quadrats were made daily at 1000. We conducted 4 replicates, each with a new group of 10 birds. Daily seed consumption was subjected to a 3-way ANOVA with color as a main effect, bird group as a random block effect, and day as a repeated measure.

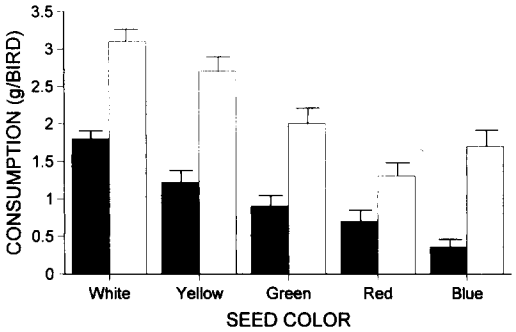

Fig. 1. Mean consumption by individually caged male red-winged blackbirds of colored rice seed during 30-min (shaded bars) or 3-hr (open bars) feeding trials. Each bird received all colors in 10 pairwise presentations. Capped vertical bars denote 1 standard error.

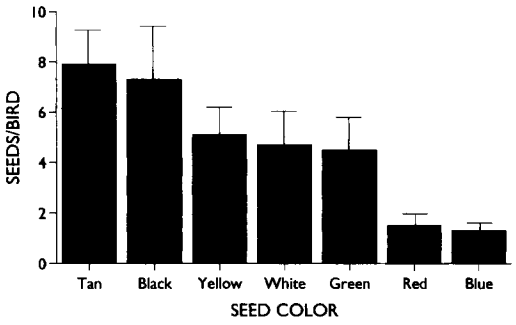

Fig. 2. Mean consumption by individually caged male red-winged blackbirds of colored rice seeds during 4 5-min feeding trials. Each bird received 30 seeds of all 7 colors in a single cup. Capped vertical bars denote 1 standard error.

RESULTS

Test 1. Individual Red-Winged Blackbirds 30-Min and 3-Hr Pairwise Color Preference

In 30-min feeding trials, seed consumption varied ($F_{4,72} = 41.19$, $P < 0.001$) with color. White was eaten the most and blue the least (Fig. 1). Pairwise comparisons among the 5 colors were all different ($P < 0.05$). The interaction between bird and color ($F_{44,72} = 2.67$, $P < 0.001$) indicated variability among birds in responses to different colors. For example, 8 birds ate blue seeds the least but, for 1 bird, consumption of blue seeds was second only to white.

Rice seed consumption in the 3-hr trials varied ($F_{4,72} = 20.51$, $P < 0.001$) with color (Fig. 1), but pairwise comparisons revealed no differences ($P > 0.05$) between white and yellow or between red and blue. As in the 30-min trial, there was an interaction between bird and color ($F_{44,72} = 2.51$, $P < 0.001$).

Test 2. Individual Red-Winged Blackbird 5-Min Color Preference Trial

Mean seed consumption during 5-min trials ranged from 20 to 45 seeds/bird. No bird removed all 30 seeds of any 1 color during a single trial, although white, green, and black were reduced to 1 seed once each. Consumption of colored seed was nonrandom ($F_{6,66} = 3.31$, $P = 0.007$), with tan seeds (colored to resemble natural rice seed) eaten the most and blue and red seeds eaten the least (Fig. 2). Consumption of white, yellow, green, and black seeds did not differ from tan ($P > 0.05$).

Total seed consumption did not differ among birds ($F_{11,66} = 0.44$, $P = 0.931$), but birds selected among colors differently ($F_{66,198} = 5.01$, $P < 0.001$). For example, white, black, and green were each the least favored color by 1 or more birds and also the most favored color by 1 or more other birds. There was no interaction between trial and color ($F_{18,198} = 1.23$, $P = 0.240$).

Test 3. Group Red-Winged Blackbird Multicolor Pen Test

Seed color selection by the 8 blackbird groups given terra cotta food cups was not different from random ($\chi^2_6 = 7.50$, $P = 0.277$). Similar results were obtained from the 8 groups that received gray food cups ($\chi^2_6 = 9.25$, $P = 0.160$). When results from all 16 test groups were combined, however, seed color removal was nonrandom ($\chi^2_6 = 14.41$, $P = 0.025$). Blue (χ^2 contribution = 5.50) remained in the set of final 3 colors of 13 groups, while tan (χ^2 contribution = 5.01) remained once (Fig. 3). Other colors remained in 4–9 trials.

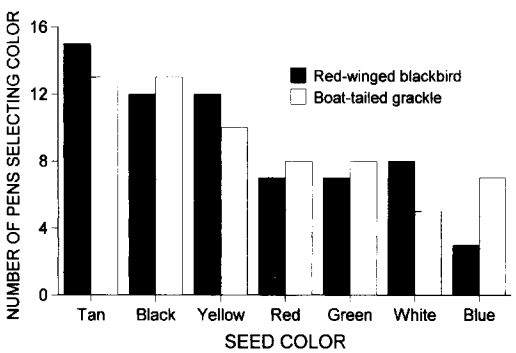

Fig. 3. Number of pens (out of 16 possible) that after 4 days of testing included each of 7 rice seed colors in the final set of most preferred colors. The red-winged blackbird pens held 3 males/pen, and the boat-tailed grackle pens held 1 male/pen. Under the null hypothesis, each color should have been selected in 16 × (4/7) = 9.1 pens.

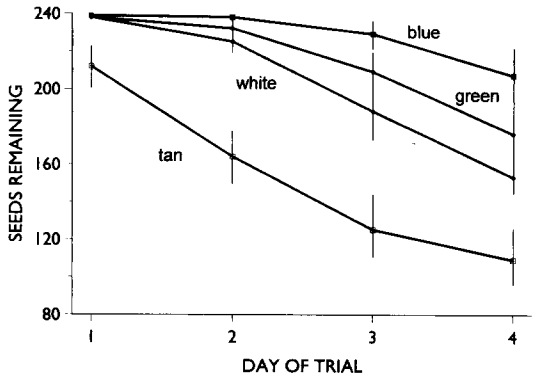

Fig. 4. Removal of blue, green, white, and tan-colored rice seed from experimental plots during 4-day feeding trials within a 0.2-ha flight pen by 4 groups of 10 male red-winged blackbirds. Each group of birds started with 240 seeds of each color. Vertical lines denote 1 standard error.

Test 4. Individual Boat-Tailed Grackle Multicolor Pen Test

After 4 days, white seed remained in 11 of the 16 pens, and blue remained in 9 (Fig. 3). Other colors were represented 3–8 times each. There were no statistical differences in color selection for groups exposed to either terra cotta food cups ($\chi^2_6 = 9.25$, $P = 0.160$), gray food cups ($\chi^2_6 = 2.83$, $P = 0.830$), or for the groups combined ($\chi^2_6 = 7.99$, $P = 0.238$).

Test 5. Red-Winged Blackbird Groups in Flight Pen

Daily seed removal varied ($F_{3,9} = 17.97$, $P < 0.001$) among colors, with tan-colored seeds taken the most (32.8 ± 4.4 seeds/day; $\bar{x}$ ± SE), and blue seed removed the least (8.3 ± 3.3 seeds/day). Post hoc analysis showed that consumption of tan seeds was distinct ($P < 0.05$) from each of the other colors, but consumption of blue did not differ ($P > 0.05$) from green (16.1 ± 4.2 seeds/day). Total seed removal ranged from 24.7 to 45.8% among replicates. Seed consumption varied with day ($F_{3,27} = 11.85$, $P < 0.005$), as birds removed fewest seeds on day 1 (8.0 ± 4.0 seeds/day) and most on day 3 (27.1 ± 4.4 seeds/day). The interaction between day and color ($F_{9,27} = 5.69$, $P < 0.001$) reflected the fact that tan seed was taken preferentially on days 1–3, whereas tan seed had been substantially depleted on day 4, and birds turned to each of the other 3 colors (Fig. 4).

DISCUSSION

Among the several colors we applied to rice seed, blue was consistently the least preferred by blackbirds. The initial effectiveness of blue as a blackbird-deterrent seed color was due, in part, to the novelty of blue seeds. Because blackbirds never encounter blue seeds in their normal foraging, in 30-min trials they preferentially selected other more normal looking seeds. After increased exposure to blue seeds during the 3-hr trial, the novel effect waned and the immediate, decisive color preferences shown by individuals in the 30-min trial were ameliorated as birds overcame initial seed color biases.

The vision of many diurnal bird species extends into near ultraviolet wavelengths (<400 nm), below the threshold of detection by the human eye (Parrish et al. 1984). For red-winged blackbirds and several other species, maximum spectral sensitivity is in the near ultraviolet, at 370 nm (Chen and Goldsmith 1986). Therefore, the reflectance of ultraviolet light from the blue seeds possibly contributed to the birds' avoidance of that color. Additional study of the role played by ultraviolet reflectance in avian avoidance responses is warranted.

As in cage trials with individual birds, pen trials with groups of blackbirds showed that blue was the most consistently avoided color regardless of background color. At least 1 study (Goforth and Baskett 1971) has reported an effect of background color on seed selection by birds. Others, however, have found no effect of background color (Pank 1976, Gionfriddo and Best 1996). Our tests were not sufficiently sensitive to demonstrate statistically significant differences in color selection on each of the 2 backgrounds, and the effect of background color remains a fruitful area for additional study.

MANAGEMENT IMPLICATIONS

Consistency in responses among individuals and test groups exposed to colored rice seed demonstrates that blue is the color least preferred by red-winged blackbirds and boat-tailed grackles among those we tested. Similar responses to blue in other contexts have been reported for other species. For example, Gionfriddo and Best (1996) found blue and black to be the least preferred grit color by house sparrows (*Passer domesticus*) and northern bobwhite (*Colinus virginianus*). Also, house sparrows and European starlings (*Sturnus vulgaris*) avoided blue-dyed food in choice tests with untreated food (Greig-Smith and Rowney 1987). Conversely, blue elicited the strongest pecking response in 1-day-old northern bobwhites (Mas-

trota and Mench 1995), and blue food was consumed the most by European starlings in bait preference trials (Schwab 1964). Thus, although blue appears the best color to reduce ingestion of seeds by blackbirds, at this time there is insufficient information to extend these findings to other species. Nevertheless, until additional information becomes available, we recommend that blue be incorporated into seed treatment formulations as a general practice to discourage feeding by granivorous birds.

Color alone will not protect seeded crops from bird depredations, but such offensive visual stimuli should be part of integrated management plans for avian seed predators. Design and application of new visual deterrents should exploit the sensitivity of red-winged blackbirds, and other diurnal bird species, to wavelengths in the near ultraviolet portion of the spectrum.

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